Soils at B.C.I.T.'s Burnaby Campus:

Description and Analysis of Soils at the Factor 4 Area and Guichon Creek at the Burnaby Campus of the British Columbia Institute of Technology, Burnaby, B.C., Canada

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ABSTRACT

Soils at B.C.I.T.'s Burnaby campus in the Factor 4 area and along Guichon Creek were described and sampled by students in the Forest and Natural Areas (FNAM) and Fish, Wildlife and Recreation (FWR) programs. The main purpose was twofold: to provide new baseline information on soil and soil quality at B.C.IT. and to provide experience for students. A total of eighteen sites were sampled. Twenty-one soil samples were analyzed for 11 variables: pH, EC, % OM, %N, C/N, P, K, Ca, Mg, % coarse fragments and % fines. Results from the Factor 4 soils were compared to results from a previous reconnaissance study of Factor 4 soils, using multivariate analysis (perMANOVA and MRPP) with pH, %OM, % CF, soil drainage class, and thickness of the A horizon as variables. Results differ slightly between the 2 studies, likely because of differences in some soil characteristics, soil sampling methods, and season. Factor 4 soils also were compared to the more natural soils at Guichon Creek by ordination with non-metric multidimensional scaling. Differences between the 2 locations were tested using multivariate analysis (perMANOVA and MRPP) with pH, %OM, % CF, soil drainage class, and thickness of the A horizon as variables. Soils at the 2 locations do not differ greatly with respect to those variables, but they differ in other important ways: namely, bulk density and rooting depth. Factor 4 soils are artificial soils consisting of compacted subsoils capped with a thin (average 15 cm) veneer of topsoil. Subsoil bulk densities exceed critical thresholds for root expansion.

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ABBREVIATIONS and SYMBOLS USED in the REPORT

A	1. A surface mineral soil horizon 2. In MRPP, chance-corrected, within group agreement
Ap	A surface, mineral soil horizon that has been disturbed by Man's activities
B	B-horizon (soil horizon)
C	1. clay (soil texture) 2. Carbon 3. C-horizon (soil horizon)
Ca	calcium
CF	percentage of coarse fragments
C/N	carbon to nitrogen ratio
EC	electrical conductivity
FNAM	Forest & Natural Areas Management program
FWR	Fish Wildlife & Recreation program
K	potassium
L	loam
LS	loamy sand
Mg	magnesium
MRPP	multi response permutation procedure
N	% total nitrogen
OM	percentage of organic matter
perMANOVA	distance-based multivariate analysis of variance
P	phosphorus
p	Statistical term for Type I error determined from permutation test
S	sand
Si, SiL	silt, silt loam
SC	sandy clay
SCL	sandy clay loam
SL	sandy loam

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INTRODUCTION

Field work and initial data processing for the B.C.I.T. campus soil inventory was done by students in B.C.I.T.'s Forest and Natural Areas Management (FNAM) and Fish and Wildlife (FWR) programs under supervision of Jace Standish and Julia Alards-Tomalin. A list of student participants is in Appendix I.

Objectives

This report addresses 2 main objectives and 3 secondary ones. The main objectives are to:

- Provide baseline information on soils at the B.C.I.T. Burnaby campus
- Give experience to B.C.I.T. students in the FNAM and FWR programs in soil field descriptions and interpretation

Secondary objectives are to:

- Expand on the information from the January 2016 reconnaissance soil survey on of the Factor 4 area
- Compare Factor 4 soils to soils in a more natural setting along Guichon Creek
- Explore the use of some multivariate statistical methods for analyzing soil data

Soil mapping and formal (pedological) soil classification are not addressed.

Background

The Factor 4 area is situated in the northwest corner of B.C.I.T.'s campus in Burnaby, British Columbia (see Figures 1 and 2 below.) It has been identified as a candidate demonstration site for ecological restoration (BCIT Commons 2017). The area is heavily built up but has patches and strips of soil occupied mainly by ornamental trees and turf (see Figure 3, below). A reconnaissance soil survey was carried out by students in B.C.I.T.'s Sustainable Resource Management program during January of 2016 (see Standish 2016).

Figure 1. Location of British Columbia Institute of Technology campus in Burnaby B.C.[1]

[1] SOURCE: Auto generated MSWord Graphic 2017 from: Greene. E. 2017. "Survey of forest species within the British Columbia Instittue of Technlogy forest using the point-centered quarter method" . Report for RENR 2100 and COMM 2245. 23 March 2017. 12 pp.

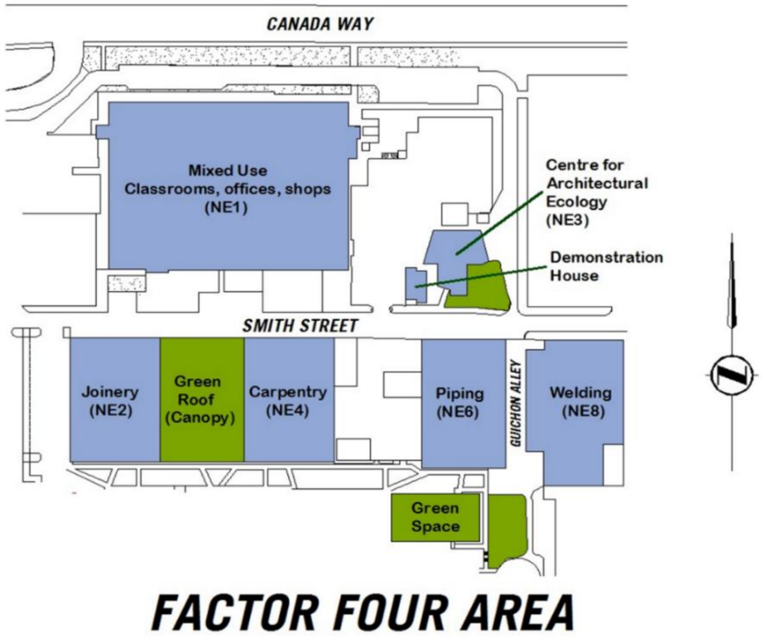

Figure 2. Factor 4 area of B.C.I.T.'s Burnaby campus

Figure 3. Green space at southeast corner of Factor 4 [2]

The Guichon Creek area of the campus is located south of Moscrop Street and west of Guichon Creek in the southern part of campus (see Figure 4, below).

[2] Photo source: S. Campbell. B.C.I.T.

Figure 4. Guichon Creek area in the southern part of the B.C.I.T. Burnaby campus [3]

The area is within the Coastal Western Hemlock, dry submaritime biogeoclimatic subzone (Government of B.C. 2016). Zonal soils are Humo Ferric Podzols[4]. It is covered with a naturally regenerated, roughly sixty-year old, seral, mainly deciduous forest, dominated by red alder (*Almas rubra* Bong.), black cottonwood (*Populus trichocarpa* T. & G. ex Hook.) and bigleaf maple (*Acer macrophyllum* Pursh). Guichon Creek is a subject for study by B.C.I.T.'s students and is being considered for stream and riparian area restoration projects (BCIT Commons 2017).

METHODS

Sample sites were randomly located within defined grid cells covering the Factor 4 and Guichon Creek areas. Two sample sites also were selected within the turf-covered area between Smith Street, White Avenue and building NW 01. Those sites are not within the limits of what is formally defined as Factor 4 but they have similar history and soils. In this report, the 2 sites are treated as if they are part of Factor 4. A total of 18 sample sites were selected: 9 for the Factor 4 and 9 in Guichon Creek areas.

Soil pits were excavated and soil profiles were described at each site following standard practices as documented in Province of B.C. (2010) and Soil Classification Working Group (1998). Horizon thickness; Munsell color; texture; structure; consistence; presence of gleying, mottling, free water surface or impervious layers; and root abundance were recorded for each horizon. Soil drainage class was also recorded. Profile descriptions for each site are on file at B.C.I.T. Examples from Factor 4 and Guichon Creek are presented below.

Bulk density was determined by measuring soil sample volume and oven-dry sample mass. Volume was found from the volume of water needed to fill a plastic-lined sample hole.

Soil samples were collected for lab analysis for pH, electrical conductivity (EC), percentage organic matter (OM), percentage total nitrogen (N), carbon to nitrogen ratio (C/N), phosphorus (P), potassium

[3] Photo source: R. Greiff. 2017. "A baseline tree inventory of the BCIT South Campus Forest". Report prepared for RENR 2100 and COMM 2245, 24 March 2017. 14 pp.
[4] Soil subgroup in the Canadian System of Soil Classification: in the USDA Soil Taxonomy, the Haplorthod subgroup.

(K), calcium (Ca), magnesium (Mg), percentage coarse fragments (CF), percentage sand, and percentage fines. Some samples (5 of 21 lab samples) from different soil horizons (A, B and C) from each location (Factor 4 and Guichon Creek) were bulked[5]. Bulk samples included only soils from similar horizons and sites. Equal volumes of individual samples were thoroughly mixed. Lab analyses were carried out by Pacific Soil Analysis, Inc.[6] Methods followed procedures in Carter (1993), Lavkulich (1978) and McKeague (1987).

Multivariate analysis was used to explore sample data for patterns and groups. Ordination by non-metric multidimensional scaling (NMS) and group testing by distance-based multivariate analysis of variance (perMANOVA) and multi-response permutation procedure (MRPP) using PC Ord, Version 7, software (McCune and Mefford 2011 & Peck 2016) were used to investigate differences in soils between the initial Factor 4 reconnaissance study and the current study and also between the Factor 4 (current study) and Guichon Creek locations.

Non-metric multidimensional scaling is a free ordination method that works well with heterogeneous data (see Manly 2005, Greenacre and Primicerio 2013, McCune and Grace 2002). PerMANOVA is a multivariate analysis of variance based on distances (a.k.a. "dissimilarities") among sample units, rather than on means of a single response variable within groups, as in analysis of variance (see Anderson 2001). It is usually used for planned experiments where distributional assumptions of multivariate analysis of variance (*e.g.*, normality of data) are not met (McCune and Grace 2002, Peck 2016). Here, it is used to see how it compares to MRPP. MRPP is a permutation- based randomization procedure used for testing among groups (Mielke 1991, Mielke and Berry 2001, Peck 2016). It is useful in earth sciences and other fields, especially for *post hoc* testing for group differences. Advantages are that it can be used with unequal sized groups and assumptions, such as normality, and homogeneity of variance, need not be met.

Data were screened using distributions plots, boxplots and data summaries, as suggested in Peck (2016) and Zuur, *et al.* (2010). Transformations were used in order to put magnitude of measurements on comparable scales. For NMS ordination, data was relativized by maximum value for each variable. For perMANOVA and MRPP tests, data were centered and standardized. Euclidian distances were used for computation of distance matrices.

Variables used in the analysis varied among tests. For NMS, 11 soil variables were analyzed. The number of variables for perMANOVA AND MRPP tests was reduced to 5. Reasons for testing with fewer variables for the latter tests were to keep the number of variables less than the number of samples and to avoid domination by groups of highly correlated variables at the expense of less correlated ones.

No attempt was made to formally classify soils in, say, the Canadian System of Soil Classification or the USDA Soil Taxonomy.

[5] Bulking some samples was necessary to stay within budget but still get samples over a range of soil horizons and locations.
[6] Pacific Soil Analysis, Inc. (PSAI), 5- 11720 Voyageur Way, Richmond, B.C. V6X 3G9.

RESULTS and DISCUSSION

Factor 4 Soils

The location of the 9 sites for soil profile descriptions is shown in Figure 5, below. Sites 8 and 10 (shown as “CREW 8” and “CREW 10” in Figure 1), near the left side of the image, are not within the Factor 4 area but their soils are similar; they are included as Factor 4 soils.

Figure 5. Location of soil pits, Factor 4 area, B.C.I.T.[7].

Figure 6, below, shows a Factor 4 soil profile. Note the upper, dark colored, organic matter-rich, surface soil horizon (Ap horizon[8]). One or more such Ap horizons, averaging 15 cm thick and ranging from ten to thirty cm thick, overlying a relatively light colored, compacted subsoil horizon, is typical of Factor 4 soils. Organic matter content of Factor 4 Ap horizons averages 6.7%, ranging from 5.0 to 8.2%. Surface (Ap) horizons have lower pH, lower bulk density, and fewer coarse fragments compared to subsoils. Percentage of fines is similar in surface and subsurface horizons. Other important soil physical and chemical properties are shown in Tables 1 and 2, below. The values in Tables 1 and 2 are means. They include soil samples from within the rooting zone: that is, within the upper 30 cm of the soil.

Lab results for all soil samples and analyses are shown in Appendix II.

[7] Image source: L. Stott. BCIT. October 2016.

[8] An “Ap” soil horizon is defined in the Canadian System of Soil Classification as a surface mineral horizon that has been disturbed by Man’s activities.

Figure 6. Upper part of a Factor 4 soil profile showing a dark colored Ap soil horizon overlying a lighter colored subsoil.[9]

SOIL PROPERTY	VALUE or CATEGORY
Soil Texture	S, LS, SL & SC[10]
% Fines	22
% Coarse Fragments	20
Bulk Density A horizon (Mg/m3)	0.79
Bulk Density C horizon (Mg/m3)	2.16
Surface Horizon Thickness (cm)	15
Rooting Depth (cm)	30
Soil Drainage Class	Moderately well to poorly drained

Table 1. Summary of some important physical properties of Factor 4 soils.

[9] Photo source: K. Heidema, M. Scott, A. Chong & J. Rollins. Oct. 16, 2016, RENR 1130 soil report. .BCIT. 2 pp.
[10] SL and SC are the most common textures found in the soil samples.

SOIL PROPERTY	VALUE
pH	5.7
% Organic Matter	5.8
% total Nitrogen	0.18
C/N	20.5
Phosphorus ppm	54
Potassium ppm	97
Calcium ppm	1021
Magnesium ppm	86
Electrical Conductivity dS/m[11]	0.30

Table 2. Summary of some important chemical properties of Factor 4 soils.

Guichon Creek Soils

The location of soil pits along Guichon Creek are shown in Figure 7, below.

Figure 7. Location of soil pits: Guichon Creek area, B.C.I.T.[12]

A soil profile from the most northerly site, the Crew 19 soil pit, is shown in Figure 8, below. A thin (1 to 2 cm thick) surface humus horizon overlies a 12 cm thick Ap mineral surface horizon which is difficult to

[11] dS/m = deci-Siemens per metre. 1 dBs/m = 1 mmhos/cm
[12] Image source: L. Stott. BCIT. October 2016.

see in the picture. There is an 8 cm thick dark reddish brown B horizon[13] under the Ap. The B horizon is underlain by another slightly lighter reddish brown B horizon. The bottom, (C) horizon, which appears gray, consists of different parent material than the overlying B horizons. Just out of view, below the lowest part of the profile, there is a perched water table (not visible in the picture).

Figure 8. Soil profile for Crew 19, Guichon Creek[14]

Soil profiles in the Guichon Creek area are remnants of natural forest soils that have been disturbed to varying degrees. The original surface organic (humus) and mineral (A and at least some of B) horizons have been scalped or eroded away. In some locations, mineral soil materials also have been deposited either through past human actions or deposition from erosion. Profiles are variable throughout the area and details of disturbance history are unknown.

Tables 3 and 4, below, summarize physical and chemical properties for Guichon Creeks soils.

SOIL PROPERTY	VALUE or CATEGORY
Soil Texture	S, LS, SL & SC[15]
% Fines	24
% Coarse Fragments	7
Bulk Density A horizon (Mg/m3)	0.52
Bulk Density C horizon (Mg/m3)	1.32
Surface Horizon Thickness (cm)	12
Rooting Depth (cm)	58
Soil Drainage Class	Well, moderately well & imperfectly drained

Table 3. Summary of some important physical properties of Guichon Creek soils

[13] B horizons are subsoil mineral horizons showing marked modification from soil forming processes compared to the original, unaltered soil parent material that is typically found beneath in the C horizon.
[14] Photo source: E. Hofs, S. Wait and C. Westeyn. 28 Nov. 2016 soil report, RENR 1130, BCIT. 4 pp.
[15] SL and SC are the most common textures found in the soil samples.

SOIL PROPERTY	VALUE
pH	5.0
% Organic Matter	6.0
% total Nitrogen	0.17
C/N	19
Phosphorus ppm	26
Potassium ppm	53
Calcium ppm	429
Magnesium ppm	60
Electrical Conductivity dS/m	0.23

Table 4. Summary of some important chemical properties of Guichon Creek soils

Comparison of Current Factor 4 Survey to Factor 4 Soil Results from Previous Survey[16]

The first Factor 4 soil survey, carried out during late January of 2016, was a reconnaissance, sampled mainly surface soil using soil augurs. The current survey was conducted using soil profile descriptions and soil samples from excavated pits. While the surveys were not designed to be compared, their similarities and differences deserve discussion. Table 5, below, compares values of soil characteristics for surface horizons in Factor 4 from 2 different surveys.

The mean values for most characteristics listed in Table 5 are greater for the 1st survey than for the second, except for C/N, electrical conductivity and % coarse fragments. Differences are large for phosphorus, potassium, calcium and magnesium and moderate for % organic matter. Differences are very small for % total nitrogen, electrical conductivity and % coarse fragments. Difference in C/N is moderate but C/N is still low enough that it might not make much difference. With respect to pH, a difference of 0.4 is not necessarily important, although nitrogen availability might be reduced at pH below 5.8[17].

In order to verify difference between the 2 studies, a bootstrapped perMANOVA was carried out using 5 selected soil variables from upper (A and B) soil horizons: pH, % OM, % CF, soil drainage class, and thickness of the A horizon. Choice of variables was based on their edaphic importance, independence, magnitude, pattern of variation, and relative ease of measurement[18]. For example, % coarse fragments and soil horizon depth can be readily determined from field observations. Also, they are ecologically important with respect to vegetation and show a range of variation and correlations in the Factor 4 data. Other examples are % OM and pH. Soil organic matter is well known to be important in improving soil physical properties and as a source of nutrients, especially nitrogen. Percentage of organic matter is strongly, positively, and linearly correlated with % N (see Figure 9, below) and also with P and K (not shown). Soil pH is relatively inexpensive to measure and is a useful index of plant nutrient availability.

[16] See: Standish, J. 2016. "Factor 4 soil report: a survey of soils at the Factor 4 project area, British Columbia Institute of Technology, B.C.I.T. Campus", 16 May 2016. 15 pp. (Field work was carried out in late January 2016.)
[17] For many crops pH < 5.6 is considered low (NRCS 1998).
[18] See: NRCS 1996

SOIL PROPERTY	FACTOR 4: 1ST SURVEY	FACTOR 4: 2ND (CURRENT) SURVEY[19]	DIFFERENCE (1st -2nd)
pH	6.1	5.7	0.4
% Organic Matter	7.4	5.8	1.6
% total Nitrogen	0.23	0.18	0.05
C/N	13	20.5	-7.5
Phosphorus ppm	111	54	57
Potassium ppm	148	97	51
Calcium ppm	1359	1021	338
Magnesium ppm	109	86	23
Electrical Conductivity dS/m	0.28 dS/m	0.30	-0.02
Soil Texture	L, SiL, SCL & SL	S, LS, SL & SC[20]	
% Fines	n/a	22	
% Coarse Fragments	16	20	-4
Surface Horizon Thickness (cm)	Not sampled[21]	15	nil
Soil Drainage Class	Moderately well to poorly drained	Moderately well to poorly drained	nil

Table 5. Comparison of soil characteristics for 2 Studies of Factor 4 soils

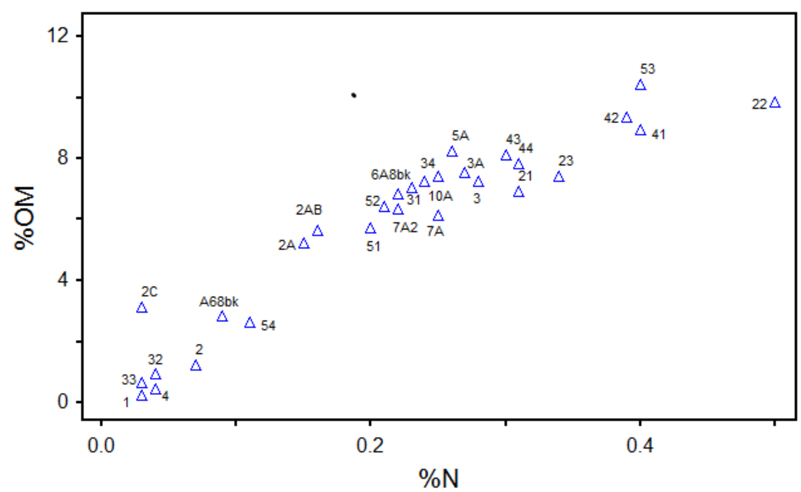

Figure 9. Scatter plot of % OM *vs.* % N for Factor 4 soils[22]. Plots of organic matter *vs.*, P and *vs.* K (not shown) are similar but have more scatter at higher nutrient values.

Results of perMANOVA are significant (F = 4.002, p = 0.00580). MRPP was also carried out. Results were significant (T = - 4.374, and p = 0.00318) but the chance-corrected within group agreement value (A), a measure of effect size, is small (A = 0.06355). This is probably because of greater heterogeneity of

[19] October and November 2016.
[20] SL and SC are the most common textures found in the soil samples.
[21] Estimated mean thickness is in the 10-15 cm range.
[22] Data is from 2 studies: January 2016 and November 2016.

some soil variables in one survey compared to the other. For example, boxplots and summary data show greater heterogeneity of % OM, % N and P for the first study and greater heterogeneity for K in the second. The magnitude of differences in means is not important with respect to anticipated land use in Factor 4; for example, while there are relatively large differences in P, K, Ca and Mg between the 2 studies, the lower values are still within an acceptable range for most plants. There is a statistically significant difference between the 2 surveys but the magnitude of difference is small.

Differences observed in some soil variables between the 2 surveys reflects sampling error and differences in sampling methods. Reasons for differences may be:

- The first study was conducted using cores from soil augurs. It is relatively difficult to prevent some mixing of upper and lower soil horizons with augur samples.
- The first study included a number of samples from landscape planting areas rather than only areas of turf; soils in those areas differ, especially with respect to % organic matter, % nitrogen and other nutrient elements.
- The studies occurred at different times: seasonal weather varies (*e.g.*, January 2016 *vs*. November 2016). That affects soil biology and chemistry.

<u>Comparison of Factor 4 Soils and Guichon Creek Soils</u>

The Factor 4 and Guichon Creek areas differ in their soil profiles and their site histories. The Factor 4 area has experienced greater disturbances including clearing, grading, deposition and compaction of fill material, and deposition of a thin (average = 15 cm) surface (topsoil) horizon. Soils along Guichon Creek have been less severely disturbed and, at least in many places, appear to have retained some remnants of their original forest soil profiles. Their surface soil horizons appear to have developed mainly under the influence of natural processes associated with forest succession and soil development. So, to a degree, Guichon Creek soils provide a baseline for comparing Factor 4 soils to more natural soils within an area of similar climate and somewhat similar topography.

In order to give an overall picture of soil properties in the 2 areas, ordination by non-metric multidimensional scaling (NMS) was carried out. Eleven soil variables were included: pH, EC, % OM, %N, C/N, P, K, Ca, Mg, % CF and % fines. A significant ($p \leq 0.012$), 3-dimensional solution with a final stress of 5.6 was chosen after verifying the consistency of interpretation among 5 NMS solutions. Cumulative coefficients of determination for the correlations between ordination distances and the original distance matrix for the 3 axes are .416, .741 and .963 for axes 1, 2 and 3, respectively. Three soil variable gradients, representing combined effects of the soil variables, were identified:

- Gradient 1 (Axis 1): increasing K, P, % N, Mg, EC and % OM
- Gradient 2 (Axis 2): moderately decreasing Ca, pH and % CF
- Gradient 3 (Axis 3): decreasing Ca, pH, EC, % fines, Mg and P

A graph of the first 2 gradients (axes 1 and 2) is shown below in Figure 10. Location 1 is Factor 4; Location 2 is Guichon Creek. Hollow (red) triangles represent Factor 4 sample sites: solid triangles (green) Guichon Creek. Numbers next to the triangles are soil sample numbers (see Appendix II). The crosses represent the centroids for the locations. The red-shaded polygon includes all Factor 4 soil sample locations; the green-shaded – Guichon Creek. The NMS results are interpreted as showing an increase in the combined influence of K, P, % N, Mg, EC and % OM from Factor 4 soils to Guichon Creek soils (left to right on axis 1) and a decrease in Ca, pH, EC, % fines, Mg, P and % CF from Factor 4 soils to Guichon Creek soils (axes 2 and 3 – but axis 3 is not shown below).

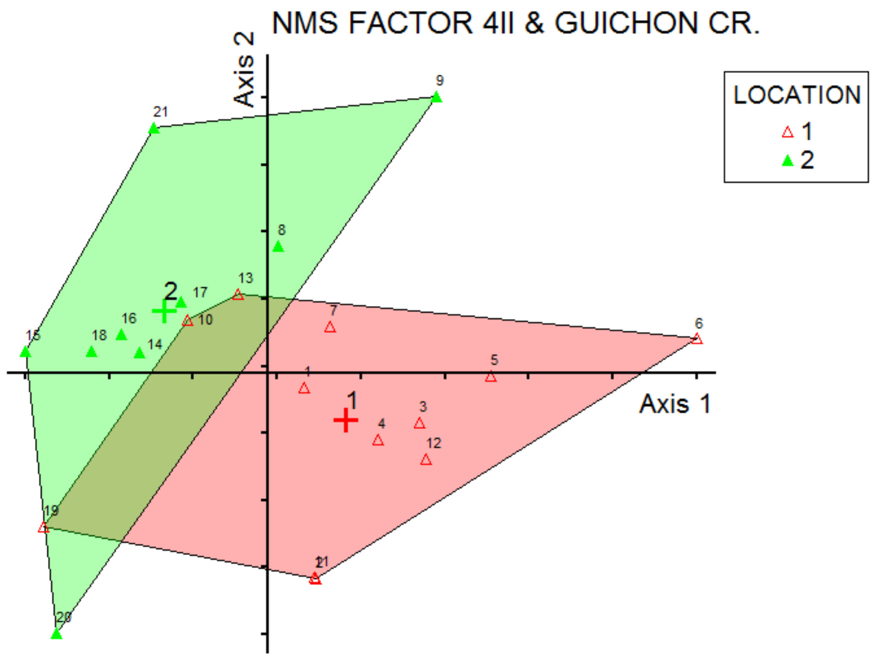

Figure 10. Graph of NMS showing locations of soil samples and their centroids for the first 2 soil gradients (axes). ("FACTOR 4II" refers to the current soil survey of the Factor 4 area.)

The NMS results are included to show some general trends and groupings. With respect to grouping by location, the centroids (crosses) are separated but there are 3 out of 21 samples (14%) that overlap between locations.

Mean values for Factor 4 and Guichon Creek soil properties are shown in Table 6, below. Values are from surface (both A and B) horizons with the exceptions bulk density, horizon thickness, root zone depth and soil drainage class. Factor 4 values are greater than Guichon Creek for all chemical properties except % OM, which is marginally greater for Guichon Creek soils. Mean bulk density, surface horizon thickness, and % CF are greater for Factor 4. Mean % fines is slightly greater for Guichon Creek. Mean rooting depth is much greater for Guichon Creek soils. Soil drainage class and texture are more or less similar, but well drained soils may be more common for Guichon Creek.

SOIL PROPERTY[23]	FACTOR 4[24] (2ND SURVEY)	GUICHON CREEK	DIFFERENCE (= FACTOR 4 - GUICHON)
pH	5.7	5.0	0.7
% Organic Matter	5.8	6.0	- 0.2
% total Nitrogen	0.18	0.17	0.01
C/N	20.5	19	1.5
Phosphorus ppm	54	26	28
Potassium ppm	97	53	44
Calcium ppm	1021	429	592
Magnesium ppm	86	60	26
Electrical Conductivity dS/m	0.30	0.23	0.07
Soil Texture	S, LS, SL & SC[25]	S, LS, SL & SC[26]	Similar
% Fines	22	24	-2
% Coarse Fragments	20	7	13
Bulk Density A horizon (Mg/m3)	0.79	0.52	0.27
Bulk Density C horizon (Mg/m3)	2.16	1.32	0.84
Surface Horizon Thickness (cm)	15	12	3
Rooting Depth (cm)	31	58	-27
Soil Drainage Class	Moderately well to poorly drained	Well, moderately well & imperfectly drained	similar

Table 6. Comparison of soil characteristics for Factor 4 *vs.* Guichon Creek Soils

A bootstrapped perMANOVA test for difference between Factor 4 and Guichon Creek soils with respect to 5 variables was carried out. The 5 soil variables are thickness of the soil horizon, % CF, % OM, pH, and soil drainage class. Eight samples from each location were randomly selected with replacement for 1000 runs. The test was of marginal significance: $p = 0.0634$ with an F value of 2.826. (A p-value of ≤ 0.05 is preferable). PerMANOVA may not be the best test for the data; Type II error[27] may be large because of the small number of samples (see Peck 2016). The same variables were tested with bootstrapped MRPP. Results were significant: $p = 0.003182$: $T = - 4.374$. The chance-corrected within-group agreement ("A") is 0.063553. While the centroids of the 2 soil locations (Factor 4 and Guichon Creek) are well-separated, there is much dispersion of the values within each group. That is illustrated by the NMS graph in Figure 6 by the spread of samples (triangles) around their respective centroids (crosses) for the 2 locations.

[23] Soil properties are from root zone horizons (A and B) unless otherwise stated.
[24] Current survey
[25] SL and SC are the most common textures found in the soil samples.
[26] SL and SC are the most common textures found in the soil samples.
[27] Type II error is the risk of accepting the null hypothesis when the alternative hypothesis is true.

Given the small p-values for perMANOVA and the small effect size from MRPP, it is concluded that soils at Factor 4 and Guichon Creek, with respect to the variables analyzed, differ significantly. But the magnitude of difference may not be important with respect to potential for plant survival and growth.

Regarding the results of statistical tests using NMS, perMANOVA, and MRPP carried out on selected soil variables, it is emphasized that Factor 4 and Guichon Creek soils are qualitatively different. Factor 4 soils are artificial creations composed of compacted fill covered with a veneer of topsoil and turf. Guichon Creek soils are remnants of original forest soils supporting naturally regenerated, seral forest vegetation. Guichon Creek soils are lower in bulk density and higher in porosity with deeper rooting. In addition, there undoubtedly are important differences in soil biology and chemical cycling that are not addressed in this report.

The higher pH and nutrient concentrations in Factor 4 are likely a remnant from past fertilization and liming. They are not necessarily important with respect to soil quality for plant growth. Rooting depth in Guichon Creek soils is nearly twice that of Factor 4. Rooting in Factor 4 soils is restricted mainly to one or sometimes two, relatively thin topsoil horizons. Comparing the mean rooting depths shown in Table 6, there is nearly ninety percent more root volume which plants can exploit in the Guichon Creek soils. The increased rooting volume should compensate for slightly greater concentrations of nutrients in Factor 4 soils. Roots in Factor 4 soils are apparently restricted by high soil bulk density. Craul (1999) states that a soil bulk density of 1.33 Mg/m^3 is "nearly ideal" and suggests a general bulk density threshold of 1.60 Mg/m^3 for impedance to root growth[28]. Factor 4 subsoil bulk densities are high enough to impede root growth. Mean bulk densities for surface horizons at both locations are below limiting bulk density thresholds such as those in Craul (1999) and Urban (2008).

Nevertheless, some surface soils in Factor 4 also have been compacted, probably from foot traffic. A pocket penetrometer survey carried out during May 2016 in the large turf area in Factor 4, just south of building NE 6, to measure penetration resistance of surface soil, showed a mean surface resistance of 0.92 MPa. The 95% confidence interval is 0.29 – 1.58 MPa. Values in the range of 0.5 – 1.0 MPa are known to reduce root elongation (Cook *et al*. 1996).

<u>Soil Quality</u>

Soil quality is defined [29]as "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to:

- sustain plant and animal productivity
- maintain or enhance water and air quality
- support human health and habitation.

Changes in the capacity of soil to function are reflected in soil properties that change in response to management or climate". Soil quality is assessed in this study based mainly on 5 to 12 soil properties, including pH, % OM, total % N, C/N, P, K, EC, soil texture class, % fines, % CF, bulk density, soil drainage

[28] Thresholds vary with soil texture. For textures in this study, a threshold in the range of 1.55 to 1.65 Mg/m^3 is likely appropriate.
[29]NRCS. 2001.

class and root zone thickness. A comparison of 8 Factor 4 and Guichon Creek soil properties to USDA soil quality guidelines is shown in Table 7, below.

SOIL PROPERTY	GUIDELINE[30]	FACTOR 4 (2ND SURVEY)	GUICHON CREEK
pH	6.0 – 7.5	5.7	5.0
% Organic Matter	≥ 5	5.8	6
% total Nitrogen	0.2 – 0.6	0.18	0.17
C/N	≤ 20	20	19
Phosphorus	>20	54	26
Potassium ppm	>150	97	53
Soil Texture	L, SiL, SCL, SL or CL	S, LS, SL & SC[31]	S, LS, SL & SC[32]
% Coarse Fragments	< 10	20	7

Table 7. Comparison of Selected Chemical and Physical Soil Properties: Factor 4 *vs*. Guichon Creek vs. General Soil Quality Guidelines

Table 8, below, compares some additional soil characteristics between Factor 4 and Guichon Creek. [The information is the same as in part of Table 6 (above) but is repeated here for reader's convenience.]

SOIL PROPERTY	FACTOR 4	GUICHON CREEK
Bulk Density A horizon (Mg/m^3)	0.79	0.52
Bulk Density C horizon (Mg/m^3)	2.16	1.32
Surface Horizon (A) Thickness (cm)	15	12
Rooting Depth (cm)	31	58
Soil Drainage Class	Moderately well to poorly drained	Well, moderately well & imperfectly drained

Table 8. Comparison of Selected Soil Properties: Factor 4 vs. Guichon Creek

Both locations, Factor 4 and Guichon Creek, are within guideline limits for % OM, C/N, P and bulk density but are low with respect to pH, % N, and K. However, plant nutrient levels are adequate for the general land use objective of maintaining a more or less natural, self-sustaining ecosystem. Soil texture classes are roughly comparable between the 2 locations. Both have sandy clay (SC) textures in some

[30]SOURCE: Hanks and Lewandowski 2003.

[31] SL and SC are the most common textures found in the soil samples.

[32] SL and SC are the most common textures found in the soil samples.

horizons: a texture class not listed as an indicator of good quality. However, the SC horizons in this survey are close to the borderline of clay loam and (CL) and sandy clay loam (SCL) texture class, both of which are listed as indicators of good quality in the guidelines.

Subsoil bulk density (C horizon) is high for Factor 4 because it consists of intentionally compacted soil. Mean A-horizon thickness is slightly greater for Factor 4 soils. As previously discussed, mean rooting depth is almost twice as much for Guichon Creek compared to Factor 4 soils. Both locations include moderately well and imperfectly drained soil drainage classes but well drained soils are more common at Guichon Creek.

SUMMARY and CONCLUSIONS

A soil inventory was carried out in November 2016 on the B.C.I.T. campus in Burnaby, B.C. to further investigate the quality of soil in the Factor 4 area on the north part of the campus. The survey was also extended to include a more natural, forested area in the southern part of the campus, along Guichon Creek. Soils were described and sampled from 18 sites. Nine sites are in the highly disturbed and developed north campus where soils consist of compacted fill covered with a thin layer of topsoil and turf. Seven of those sites are in the formal Factor 4 area. Two sites are outside Factor 4, but in an adjacent area with similar conditions so they are regarded as Factor 4 sites. Nine sites are located along Guichon Creek.

Soil profiles were described and laboratory analysis of soils was carried out for pH, EC, % OM, % N, C/N, P, K, Ca, Mg, % coarse fragments and % fines. Results from current Factor 4 survey was compared to results from a previous reconnaissance study carried out in January 2016. The previous inventory employed augur sampling, mainly of surface soil; it did not include soil profile descriptions. The two Factor 4 surveys were tested for differences based on 5 selected soil properties (pH, % OM, % CF, soil drainage class, and thickness of the A horizon) using bootstrapped perMANOVA and MRPP. Both tests showed a significant ($p < 0.01$) difference between surveys. However, the magnitude of difference is not great. Differences are thought to be due to the use of different sampling methods (augur *vs*. soil profiles), seasonal differences that may have affected soil biology and chemistry, and the inclusion of soils in landscape planting areas (*vs*. turf) that were not represented in the current survey.

Factor 4 soils (current survey) were compared to Guichon Creek soils using ordination by NMS on 11 soil variables. Differences between the 2 soil groups (locations) were tested based on 5 selected soil variables (pH, % OM, % CF, soil drainage class, and thickness of the A horizon) using bootstrapped perMANOVA and MRPP. The NMS ordination showed clear separation, although with some overlap, of Factor 4 and Guichon Creek soils along a gradient of increasing combined effect of K, P, % N, Mg, EC and % OM. A bootstrapped perMANOVA test for difference between the 2 soil locations was not significant ($p = 0.0634$) but bootstrapped MRPP was ($T = - 4.374$, $p = 0.00318$). However, the effect size is small. Factor 4 and Guichon Creek soils differ statistically, with respect to the 5 soil properties used in the analysis, but the magnitude of difference is small. Nevertheless, Factor 4 and Guichon Creek soils differ in some other important respects. Factor 4 soils are man-made soils consisting of dense, compacted fill overlain with a veneer of topsoil. Guichon Creek soils are disturbed remnants of natural forest soils with more favorable physical properties and averaging roughly twice the rooting depth of Factor 4 soils.

Regarding project objectives:

- Soil information gathered greatly improves the baseline information on soils in Factor 4 and for the B.C.I.T. campus in general. From the January 2016 survey, there is lab data for 20 soil samples, mostly from surface horizons. There are now 21 more soil samples from 18 more sites, along with soil profile descriptions.
- 31 FNAM and 28 FWR students gained experience describing, sampling and interpreting soils.
- There now is soil information for 9 sites along Guichon Creek
- Factor 4 soils are compared to Guichon Creek soils and found to have
    - some similarities in some soil properties, namely pH, % OM, % CF, soil drainage class, and thickness of the A horizon,
    - important differences that can affect soil quality and productivity, specifically bulk density and rooting depth.
- Multivariate analysis methods, particularly ordination with NMS and groups testing with perMANOVA and MRPP were found to be useful:
    - Ordination by NMS can be useful for exploring soil data.
    - PerMANOVA tests with small numbers of samples (8 per group in this study) and similar data characteristics may fail to detect a difference because of bias toward Type II error.
    - MRPP, compared to perMANOVA, is more suited for smaller sample numbers or when there are unequal numbers of observations.

With respect to general soil quality, Factor 4 soils have mostly low to adequate concentrations of soil macronutrients and favorable soil texture. For maximum productivity, fertilization with N, P and K would be needed. Factor 4 soils are equal or greater in soil nutrient concentrations compared to Guichon Creek soils. An important difference is that Guichon Creek soils have more favorable physical properties and greater rooting depth. Major limitations of Factor 4 soils are related to high subsoil density and related effects on aeration, drainage and mechanical root impedance. There is also surface compaction in some places. Tillage to about a 60 cm depth with some additions of organic matter would be an appropriate preparation for establishment of healthy, self-sustaining vegetation such as native or ornamental trees and shrubs. Some artificial drainage measures might also be useful in some sites. Maintenance of the current turf cover would benefit from aeration and management of foot traffic.

LITERATURE CITED

BCIT Commons. 2017. “Daylighting Guichon Creek”. BCIT. http://commons.bcit.ca/factorfour/2014/11/13/daylighting-guichon-creek/ . Mar.20, 2017.

Carter, M.R. (ed.) 1993. *Soil sampling and methods of analysis*. Canadian Society of Soil Science. Lewis Publishers. 823 pp.

Craul, P.J. 1999. *Urban soils: applications and practices*. John Wiley & Sons, Inc. 366 pp.

Government of B.C. 2010. “Biogeoclimatic ecosystem classification subzone/variant map for the Chilliwack Resource District, South Coast Region”. Version 10, Aug. 2016. British Columbia Min. of Forests, Lands and Natural Resource Operations. Victoria. 1: 250 000 scale map. ftp://ftp.for.gov.bc.ca/HRE/external/!publish/becmaps/PaperMaps/field/DCK_ChilliwackResourceDistrict_SouthCoastRegion__field.pdf

Greenacre, M. and R. Primicerio. 2013. *Multivariate analysis of Ecological Data*. *Fundacion* BBVA. Bilbao, Spain. 331 pp.

Hanks, D. and A. Lewandowski. 2003. “Protecting urban soil quality: Examples for landscape codes and specifications.” USDA, Natural Resources Conservation Service. nrcs142_053275.pdf 20 pp.

Manly, B.F.J. 2005. *Multivariate Statistical Methods: A Primer*. (3rd ed.) Chapman & Hall/CRC. 214 pp.

McCune, B. and J.B. Grace. 2002. *Analysis of Ecological Communities*. MjM Software Design, Gleneden Beach, OR. 300 pp.

Mielke, P.W. 1991. “The application of multivariate permutation methods based on distance functions in the earth sciences”. *Earth Science Reviews* 31: 55 – 71.

Mielke, P. W. and K. J. Berry. 2001. *Permutation Methods: A Distance Function Approach.* Springer Series in Statistics. Springer.

NRCS 2001. “Soil Quality – Introduction”. Soil quality information sheet. USDA Natural Resource Conservation Service. June 2001. Soil Quality Institute in cooperation with the National Soil Survey Center, NRCS, USDA; and the National Soil Tilth Laboratory, Agricultural Research Service, USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052207.pdf

NRCS 1998. “Soil quality indicators: pH”. Soil quality information sheet. USDA. Natural Resources Conservation Service. Prepared by the National Soil Survey Centre in cooperation with the Soil Quality Institute and the National Soil Tilth Laboratory. Agricultural Research Service, USDA. January 1998. Washington, D.C. 2 pp.

NRCS 1996. “Indicators for soil quality evaluation”. Soil quality information sheet. USDA. Natural Resources Conservation Service. Prepared by the National Soil Survey Centre in cooperation with the Soil Quality Institute and the National Soil Tilth Laboratory. Agricultural Research Service, USDA. April 1996. Washington, D.C. 2 pp.

Peck, J.E. 2016 *Multivariate Analysis for Community Ecologists: Step-by Step*. 2nd ed. MjM Software. Gleneden Beach, OR. 162 pp.

Province of B.C. 2010. *Field manual for describing terrestrial ecosystems*. 2nd ed. co-published by Res. Br. B.C. Min. of Forest and Range and the Resource Inventory Br. B.C. Min, of Env. Victoria.

Soil Classification Working Group. 1998. *The Canadian system of soil classification*. 3rd ed. Res. Br. Agriculture and Agri-Food Canada, Publ. 1646. Ottawa. 187 pp.

Standish, J.T. 2016. "Factor 4 soil report: a survey of soils art the Factor 4 Project Area: British Columbia Institute of Technology, Burnaby, B.C. Campus". 15 pp.

Urban, J. 2008. *Up by the roots: healthy soils and trees in the built environment*. International society of Arboriculture. Champaign, Illinois. 479 pp.

Zuur, A.F., E.N. Ieno and C.S. Elphick. 2010. "A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution*. 1 (1): 3 – 14.

APPENDIX I: List of Student Participants

The following B.C.I.T. students participated in the study.

28 Fish, Wildlife & Recreation (FWR) students

Terrence Ang
Kristina Apcev
Cara Blair
Anna Bondartchouk
Kieran Braid
Shannon Cameron
Jessie Chestnut
Geric Coutts
Natalia Galvez Archila
Sarah Gray
Erin Greene
Robin Greiff
Noah Haave
Elyse Hofs
Sarah Jackson
Alexis Landsiedel
Julia Larsen
Helen Ma
Mackenzie Mercer
Maya Meron
David Muhlert
Ryan Povarchook
Allana Rose
Derek Schofield
Shane Steele
Sonia Waiz
Jessica Weiss
Cole Westleyn

31 Forest & Natural Areas Management (FNAM) students

Hayley Auld
Alexis Bryant
Alexander Chong
Lisa Davies
Brian Davis
Ryan De La Cruz
Kevin Heidema
Alexander Hyde
Torin Kelly
Denis Lock
Joshua Kreklevich
Hyang Won Lee
Michelle Lizee
Gabriel Mara
Jonathan Martel-Trombley
Samantha McGuffin
Justin Perry
Jed Phillips
Jorianna Porter
Nicholas Radford
Jon Rollins
Morgan Scott
Kelsey Smith
Brent Strong
Tanner Sulentich
Alexander Tait
Gwyn Taylor
Lucas Tilston
Sophia Wall
Han Wang
Sarah Whitford

APPENDIX II: Soil Laboratory Data

SAMPLE	pH	EC	% OM	%N	C/N	P	K	Ca	Mg	%> 2 mm	% FINES
1	6.3	0.32	5.2	0.15	20	65	109	1550	105	6	19
2	7.0	0.66	5.6	0.16	20	92	53	2900	55	37	34
3	6.4	0.44	7.5	0.27	16	97	113	1300	135	16	12
4	6.8	0.5	7.0	0.23	18	86	165	2150	100	17	26
5	5.7	0.54	8.2	0.26	18	92	185	1300	175	4	15
6	5.9	0.64	6.1	0.25	14	170	450	1400	215	6	31
7	5.7	0.4	7.2	0.24	17	81	98	1125	93	14	38
8	5.3	0.26	8.4	0.23	21	11	135	1000	130	14	31
9	4.1	0.26	19	0.57	20	22	74	160	45	17	39
10	4.8	0.24	7.1	0.19	22	13	50	400	55	18	20
11	7.0	0.66	5.6	0.16	20	92	53	2900	55	37	34
12	6.3	0.44	6.3	0.22	17	130	180	1650	110	22	20
13	6.6	0.44	2.8	0.090	18	46	60	1550	125	14	49
14	5.2	0.2	6.1	0.15	24	12	32	200	24	23	14
15	5.2	0.16	1.6	0.05	19	22	13	75	10	2	3
16	5.3	0.22	2.8	0.090	18	12	74	350	50	28	26
17	4.4	0.2	8.7	0.22	23	11	34	265	17	14	21
18	4.9	0.2	2.2	0.070	18	22	26	205	35	15	11
19	7.4	0.5	3.1	0.03	60	22	41	1900	40	41	35
20	4.7	0.18	1.4	0.04	20	76	13	40	6	81	6
21	5.4	0.18	0.20	0.01	9.0	8.9	37	900	200	13	40